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UK CL (Edition O) F1B BCAN
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(54) Attaching a noble metal chip to the electrode of a spark plug for i.c. engines

(57) The tip of the centre electrode (3) or earth electrodes (4) is melted at the predetermined regions where the noble metal chips (5) is to be fixed. Then the chip (5) is pressed into the melted region of the electrode so as to form a protruding portion (3c, 4c) along outer periphery of the chip (5). Next, the chip (5) is welded by laser light (L) through the protruding portion (3c, 4c). This method reduces thermal stress in the weld while maintaining sufficient connecting strength, reduces the size of the chip and simplifies the assembly process. The material of the chip may be Ir, Ir-Pt, Ir-Pt-Ni, Ir-Rh, Ir-W, Ir-Al, Ir-Si, Ir-Y, or Ir-Y_2O_3 and the electrode may be made from a Ni- group heat-resisting alloy containing Fe and Cr.

FIG. 2

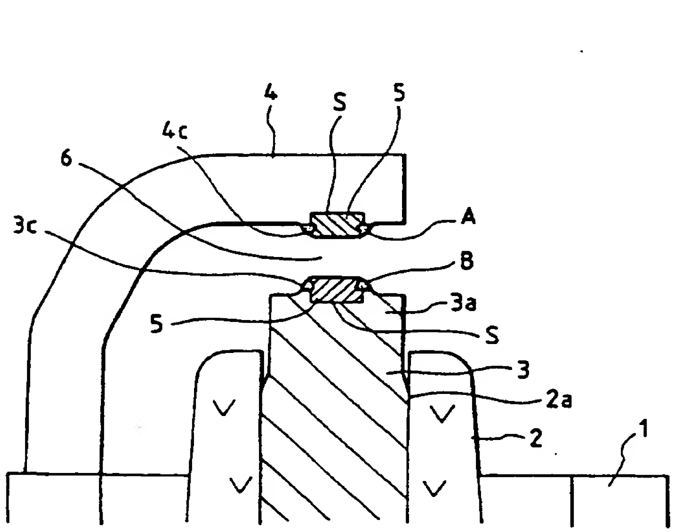
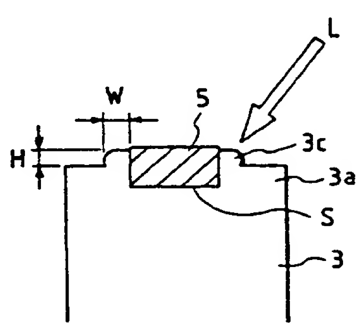


FIG. 3B



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG. 1

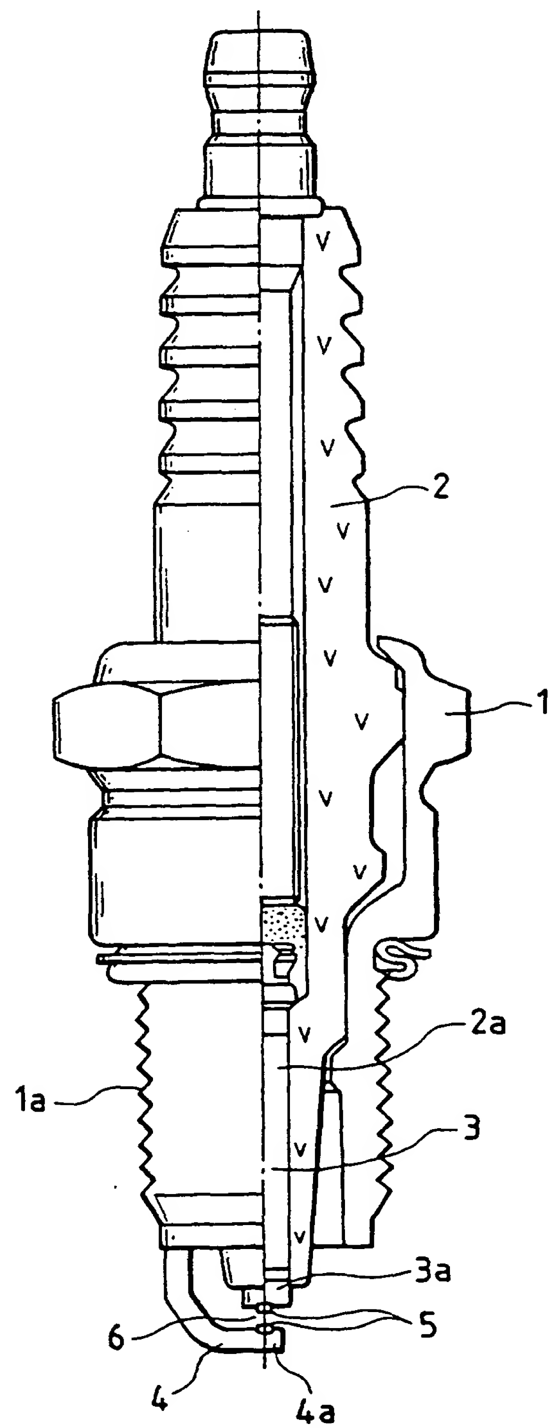


FIG. 2

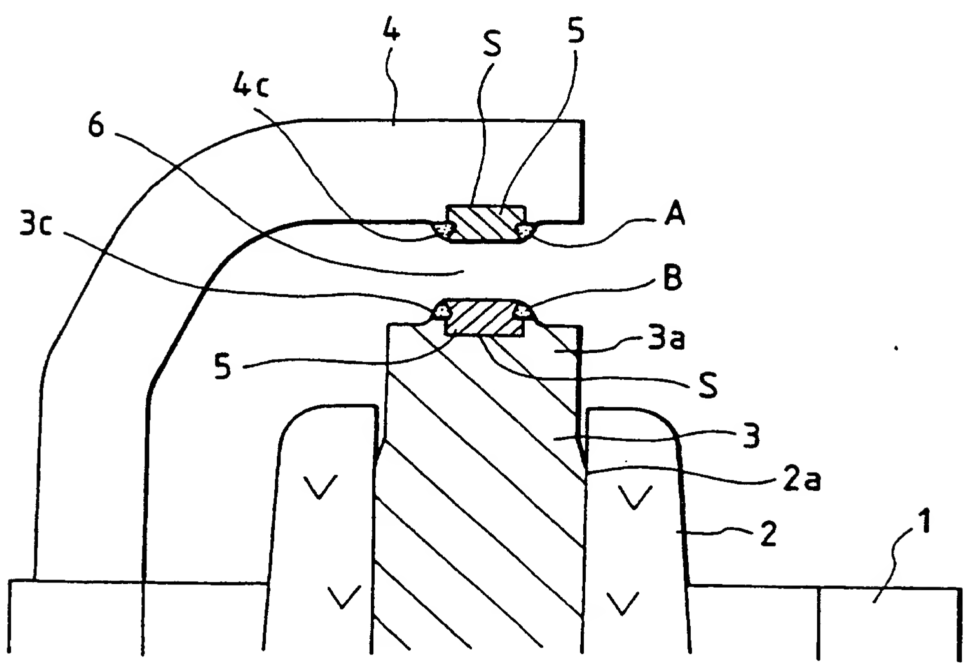


FIG. 3A

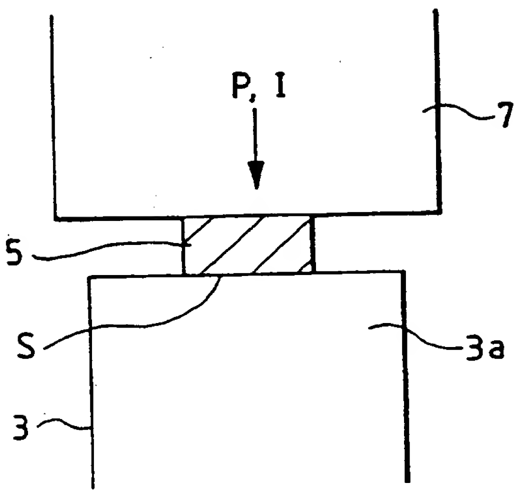


FIG. 3B

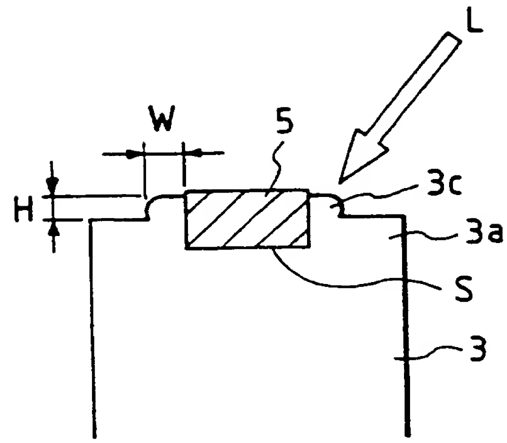


FIG. 3C

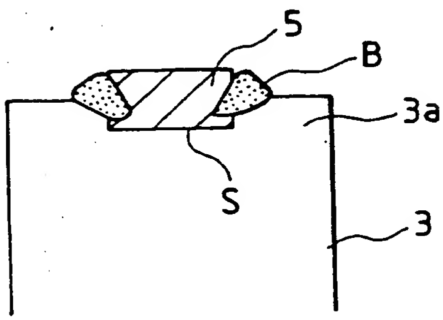


FIG. 3D

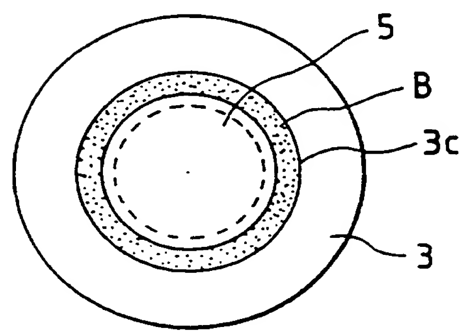


FIG. 3E

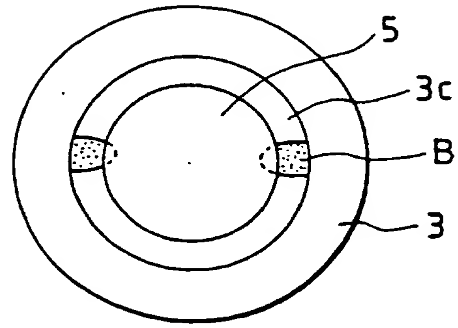


FIG. 4A
PRIOR ART

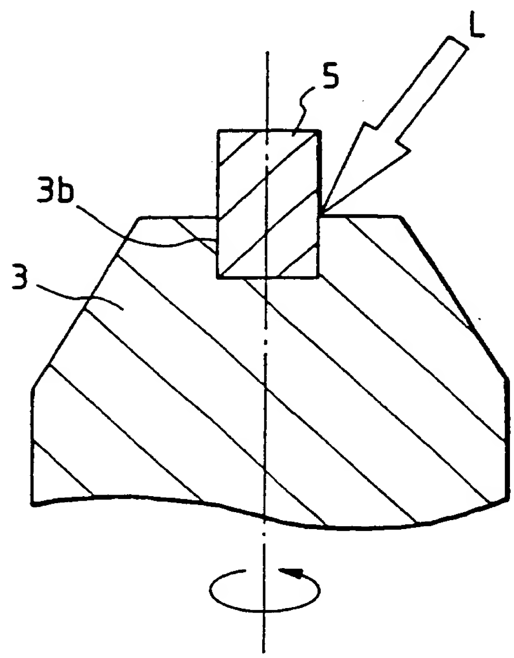
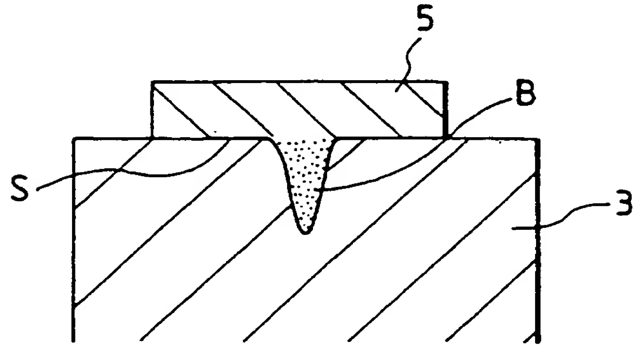


FIG. 4B
PRIOR ART



SPARK PLUG FOR AN INTERNAL COMBUSTION ENGINE

The present invention relates to a spark plug for an internal combustion engine, including a noble metallic chip provided on the tip of at least one of a center electrode and an earth electrode which cooperatively serve as a spark discharge section.

Conventional spark plugs for an internal combustion engine, known as having excellent durability, comprise a noble metallic chip 5 fixed on the tip of a center electrode 3 made of Ni-series alloy as shown in Figs. 4A and 4b. Noble metallic chip 5 is made of Ir or Pt-Ir alloy having an extremely high melting point. According to the spark plug disclosed in the unexamined Japanese patent application No. HEI 2-49388 published in 1990, a bore 3b is formed on the top of center electrode 3 as shown in Fig. 4A. A wire-like noble metallic chip 5, made of Pt-Ir alloy, is press-fitted into this bore 3b by using ultrasonic wave. Thereafter, the noble metallic chip 5 is irradiated by laser beam (indicated by L in Fig. 4A) along the entire periphery thereof.

Furthermore, according to the unexamined Japanese patent application No. SHO 57-130385 published in 1982, noble metallic

chip 5 is connected on the top of c nter electrode 3 through resistance welding operation, and then center electrode 3 and noble metallic chip 5 are securely fixed by applying laser welding along the connecting surface therebetween, as shown in Fig. 4B.

According to the above-described conventional techniques, a fusion layer (indicated by B in Fig. 4B) is formed so as to bridge center electrode 3 and noble metallic chip 5 by performing the laser welding operation in addition to the resistance welding operation. The fusion layer thus formed serves as a means for reducing the thermal stress occurring in the welding portion (indicated by S in Fig. 4B) between center electrode 3 and noble metallic chip 5 due to the difference of linear expansion coefficient between center electrode 3 and noble metallic chip 5.

However, the spark plug shown in Fig. 4A mandatorily requires the process of forming bore 3b on the top of center electrode 3. Hence, the manufacturing cost is expensive due to the formation of bore 3b. In addition, adopting the ultrasonic press-fitting operation complicates the assembling process, resulting in difficulty in welding noble metallic chip 5 on the top of center electrode 3. Furthermore, in the configuration, bore 3b is deep enough to firmly couple with noble metallic chip 5 and position it accurately. This is disadvantageous in the amount of noble metallic material used, in view of the fact that the total amount of noble metallic material is substantially

det rmined by the sum of the amount actually required for the spark discharge section and the amount sunk in the bore 3b. Thus, the cost is increased. More specifically, the thickness of noble metallic chip 5 is not smaller than 1 mm, according to the above-described conventional technology.

Furthermore, when the noble metallic chip 5 and center electrode 3 are melted by laser beam L, the portion irradiated by laser beam L and its vicinity are heated up to the temperature close to the boiling point of center electrode 3 which has a low melting point. And, the center electrode 3 possibly evaporates. In other words, the fusion layer B comes to lose the component of center electrode 3, decreasing the effect of suppressing the thermal stress occurring in the welding portion between noble metallic chip 5 and center electrod 3. Moreover, evaporation of center electrode 3 will result in the significant size reduction for the portion applied the laser welding operation. Accordingly, the connecting strength of the above-described welding portion is worsened.

The following things are estimations derived from the result of study conducted by the inventors of the present invention on the spark plug shown in Fig. 4B.

According to the spark plug shown in Fig. 4B, the laser welding is applied vertically to noble metallic chip 5 at the position closer to the center of the connecting surface between noble metallic chip 5 and center electrode 3. Hence, the fusion layer B formed through this laser welding is confined by the

surrounding portion not melted.

As explained above, center electrode 3 in the fusion layer evaporates and expands its volume, causing a force pressing or pushing its surrounding portion outwardly. After finishing the welding operation, the temperature decreases and the vaporized center electrode 3 returns to the original solid state while keeping the expanded shape of the surrounding rigid (non-melted) portion. As a result, a cavity having a volume equivalent to the expanded volume is formed inside the center electrode 3 at the welding portion S. Forming such a cavity is disadvantageous in maintaining the connecting strength at an adequate value.

Furthermore, noble metallic chip 5 and center electrode 3, before they are welded, respectively involve numerous micro holes. These micro holes gather each other and grow into a large bubble upon melting of noble metallic chip 5 and center electrode 3 in the welding operation. The large bubbl thus formed cannot go out of the welding portion S since it is completely confined by the non-melted portion. Thus, a large bubble is left in the welding portion S, reducing the connecting strength between noble metallic chip 5 and center electrode 3.

Accordingly, in view of above-described problems encountered in the related art, a principal object of the present invention is to provide a spark plug for an internal combustion engine which is capable of reducing the thermal stress causing in the welding portion between the electrode and

the noble metallic chip while maintaining a sufficient connecting strength in this welding portion between the electrode and the noble metallic chip, and further capable of simplifying the assembling process as well as reducing the manufacturing cost.

In order to accomplish this and other related objects, the present invention provides a spark plug for an internal combustion engine and its manufacturing method having various aspects which will be explained hereinafter together with reference numerals in parentheses which show the correspondence to the components of the preferred embodiments of the present invention described later.

A first aspect of the present invention provides a spark plug for an internal combustion engine comprising a c nter electrode (3), an earth electrode (4) and a noble metallic chip (5, 5) welded to at least one of center electrode (3) and earth electrode (4), wherein a protruding portion (3c, 4c) is formed around an outer periphery of noble metallic chip (5, 5) by forcibly pressing noble metallic chip (5, 5) to part of electrode (3, 4). The noble metallic chip (5, 5) is held by electrode (3, 4) through this protruding portion (3c, 4c). Through protruding portion (3c, 4c) thus formed, noble metallic chip (5, 5) is irradiated by light (L) capable of condensing energy, so that noble metallic chip (5, 5) can be welded with electrode (3, 4).

According to the first aspect of the present invention, it

becomes possible to perform the positioning and fixing operations at the same time by simply pressing the noble metallic chip (5, 5) to a predetermined fixing position on the electrode (3, 4). It results in the reduction of manufacturing steps in forming the spark plug for an internal combustion engine.

Furthermore, the present invention makes it possible to use a thin disk-shaped noble metallic chip (5, 5) because it is no longer necessary to insert the noble metallic chip (5, 5) into the deep bore (refer to Fig. 4A) formed on the top of electrode (3, 4), although such an engagement is mandatorily required in the previously-described conventional arts. It will be apparent that allowing the use of thin disk-shaped noble metallic chips will lead to a great amount of reduction of material used as the noble metallic chip (5, 5).

Furthermore, the protruding portion (3c, 4c) of the present invention is exposed to the outside. Hence, by irradiating the energy-condensing light (L) to this protruding portion (3c, 4c), both of protruding portion (3c, 4c) and electrode (3, 4) can be vaporized and then evaporated into the outside atmosphere. Accordingly, there is no possibility of causing a cavity in the fusion layer (A, B) or in the vicinity thereof even after the welding operation is finished, although the previously-described conventional arts are subjected to such a problem.

Moreover, the present invention solves the problem of the micro holes residing in the noble metallic chip (5, 5) and

electrode (3, 4) before executing the welding operation, because these micro holes can freely depart from the noble metallic chip (5, 5) or electrode (3, 4) and go into the outside atmosphere once they grew into a large bubble upon melting of the noble metallic chip (5, 5) and electrode (3, 4). Hence, the connecting strength of the welding portion (S, S) between the electrode (3, 4) and noble metallic chip (5, 5) can be adequately maintained.

Furthermore, forming the protruding portion (3c, 4c) along the outer periphery of noble metallic chip (5, 5) makes it possible to smoothly mix the protruding portion (3c, 4c) with the noble metallic chip (5, 5) when they are melted by receiving the energy from light (L). In other words, it becomes possible to prevent the undesirable reduction of the component of electrode (3, 4) involved in the fusion layer (A, B), while effectively reducing the thermal stress occurring in the welding portion (S, S).

Still further, provision of protruding portion (3c, 4c) surely prevents the size reduction of the welding portion (S, S) even if the protruding portion (3c, 4c) is evaporated more or less. Thus, the connecting strength between electrode (3, 4) and noble metallic chip (5, 5) can be properly maintained.

Yet further, according to a second aspect of the present invention, the protruding portion (3c, 4c) is formed by bringing the noble metallic chip (5, 5) into contact with the electrode (3, 4), and then melting the electrode (3, 4) at a surface

region which is brought into contact with the noble metallic chip (5, 5), thereafter sinking the noble metallic chip (5, 5) in the electrode (3, 4) melted so that part of the melted electrode (3, 4) is raised around the outer periphery of the noble metallic chip (5, 5).

Accordingly, the noble metallic chip (5,5) can be easily sunk in the electrode (3, 4) since the surface of electrode (3, 4) brought into contact with noble metallic chip (5, 5) is melted. Thus, the protruding portion (3c, 4c) can be easily formed.

Furthermore, according to a third aspect of the present invention, the protruding portion (3c, 4c) has the height not smaller than 0.1 mm and the width not less than 0.1 mm. With this configuration, reduction of the electrode (3, 4) component in the fusion layer (A, B) can be further effectively prevented. Thus, the thermal stress occurring in the welding portion (S, S) can be effectively reduced.

Yet further, according to a fourth aspect of the present invention, the noble metallic chip (5, 5) is made of noble metallic material selected from the group consisting of Ir, Ir-Pt, Ir-Pt-Ni, Ir-Rh, Ir-W, Ir-Al, Ir-Si, Ir-Y, Ir-Y_2O_3, and the electrode (3, 4) is made of Ni-group heat resisting alloy comprising Fe and Cr.

Still further, according to a fifth aspect of the present invention, the noble metallic chip (5, 5) is made of Ir alloy having linear expansion coefficient α not smaller than 8×10^{-6},

and the electrode (3, 4) is mad of heat resisting alloy having linear expansion coefficient α not smaller than 13 x 10^{-6}. In short, the present invention makes it possible to obtain a spark plug for an internal combustion engine having an excellent connecting strength between electrode (3, 4) and noble metallic chip (5, 5) even if the linear expansion coefficients of them are largely different as described above.

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description which is to be read in conjunction with the accompanying drawings, in which:

Fig. 1 is a semi-sectional view showing a spark plug for an internal combustion engine in accordance with the present invention;

Fig. 2 is an enlarged view showing the detailed arrangement of an essential part of the spark plug shown in Fig. 1;

Figs. 3A through 3C are view sequentially showing a welding method in accordance with the embodiment of the pres nt invention, Fig. 3D is a plan view showing one embodiment of the present invention, and Fig. 3E is a plan view showing another embodiment; and

Figs. 4A and 4B are enlarged views showing a conventional spark plug for an internal combustion engine.

Preferred embodiments of the present invention will b

explained in greater detail hereinafter with reference to the accompanying drawings. Identical parts are denoted by the same reference numerals throughout the views.

Fig. 1 shows a spark plug for an internal combustion engine in accordance with a preferred embodiment of the present invention. In Fig. 1, a housing 1 is cylindrical in shape and is made of heat-resistive, anti-corrosive and electrically-conductive metal. Housing 1 has a screw portion 1a which is engageable with an engine block (not shown) when the spark plug is securely installed on the engine block.

An insulating member 2, made of alumina ceramic etc., is securely accommodated in this housing 1. A center electrode 3 is fixed in an axial hole 2a extending along the axis of this insulating member 2. The center electrode 3 is made of heat-resistive, anti-corrosive, and electrically-conductive metal, such as heat-resistive nickel-group alloy comprising Fe and Cr (e.g. INCONEL 600 commercially available from Inconel Co., Ltd.: linear expansion coefficient $\alpha = 13.3 \times 10^{-6}$, melting point T_s = 1,400 °C). Center electrode 3 has a diameter of 2.7 mm. Furthermore, an earth electrode 4 is securely welded to one end of housing 1. This earth electrode 4 is made of heat-resistive, anti-corrosive, and electrically-conductive metal, too.

Noble metallic chips 5 and 5 are welded on the tip 3a of center electrode 3 and the tip 4a of earth electrode 4, respectively. These noble metallic chips 5 and 5 are made of heat-resistive, anti-corrosive, and electrically-conductive

m tal, such as Ir (linear expansion coefficient $\alpha = 6.8 \times 10^{-6}$, melting point T_m = 2,450 °C), with the diameter of approximately 0.9 mm and the thickness of approximately 0.4 mm.

Furthermore, as shown in Fig. 2, respective welding portions S and S are characterized by a fusion layer A formed between earth electrode 4 and its associated noble metallic chip 5 and a fusion layer B formed between center electrode 3 and its associated noble metallic chip 5. Both of fusion layers A and B extend from the cylindrical side wall of noble metallic chip 5 to the outside, so that fusion layers A and B are exposed to the outside atmosphere.

This welding method and the related structure for fixing noble metallic chip 5 to center electrode 3 will be explained in greater detail hereinafter with reference to Figs. 3A to 3C. The welding method for fixing noble metallic chip 5 to earth electrode 4, the structure of welding portion S and its vicinity, and their function and effect will not be explained hereinafter because they are substantially identical with those described hereinafter for the center electrode 3.

First, as shown in Fig. 3A, noble metallic chip 5 is positioned on the tip 3a of center electrode 3. Then, the resistance welding operation is performed between center electrode 3 and noble metallic chip 5 using a welding electrode 7 of a resistance welding machine.

This resistance welding operation is continuously performed during a time equivalent to 10 cycles of an alternate waveform

under the condition that pressure P = 25 kg/cm^2 and the making current I = 800 A. In this case, there is the micro undulation along the contact surface "s" where noble metallic chip 5 is brought into contact with center electrode 3 before executing the resistance welding operation. Due to such undulation, the resistance of this contact surface "s" has a very large resistance immediately after starting the resistance welding operation (more specifically, during the time corresponding to the first several cycles of the alternate waveform). Accordingly, this contact surface "s" is subjected to the most severe heat generation.

The center electrode 3 near the contact surface "s" is melted but noble metallic chip 5 remains unmelted, because the center electrode 3 has the melting point lower than that of the noble metallic chip 5 as explained above. The center el ctrode 3, after it is once melted, is brought into contact by a larger area with the noble metallic chip 5 in a wetted manner, so that the undulation is substantially canceled. Thus, the resistance of the contact surface "s" is steeply reduced.

Then, the noble metallic chip 5 is pushed toward the center electrode 3 by the pressure P applied. As shown in Fig. 3B, the melted center electrode 3 is extruded around the outer periphery of noble metallic chip 5, and is raised so as to form the protruding portion 3c. By doing so, the noble metallic chip 5 is securely fixed to the center electrode 3. Regarding the protruding portion 4c of earth electrode 4, it is formed in the

same manner as shown in Fig. 2.

Subsequently, as shown in Fig. 3B, the laser welding is applied along the outer periphery of noble metallic chip 5. In general, the laser welding is performed by condensing the energy to an intended point of the contact portion between two members, to melt the designated portion and its vicinity, thereby welding these two members. This embodiment uses YAG laser having the irradiation energy of 5J and irradiation time 5ms with a just focus (0 at the protruding portion 3c).

More specifically, the laser beam L is converged to the protruding portion 3c or its vicinity of center electrode 3 at an incident angle 45° with respect to the axis of center electrode 3. In this manner, the noble metallic chip 5 is irradiated by the laser beam L (i.e. energy-condensing light) through the protruding portion 3c. The energy of laser beam L is used to melt the protruding portion 3c corresponding to the pointing direction of arrow L, and to melt the tip 3a of center electrode 3 and the central portion of the side surface of noble metallic chip 5 in the vicinity of the above protruding portion 3c. These melted portions can be mixed each other since the protruding portion 3c of the melted center electrode 3 covers the melted noble metallic chip 5.

Accordingly, as shown in Fig. 3C, the fusion layer B is formed at the portion corresponding to the pointing direction of arrow L. More specifically, fusion layer B substantially extends from the cylindrical side wall of noble m tallic chip 5

through protruding portion 3c to th outside along the pointing direction of the energy-condensing light L.

The center electrode 3 and noble metallic chip 5 are effectively mixed in this fusion layer B. Then, the above-described laser welding is performed entirely along the outer periphery of the noble metallic chip 5 by rotating the cent r electrode 3 about its axis. By doing so, the fusion layer B is formed along the entire periphery of noble metallic chip 5 as shown in Fig. 3D.

This fusion layer B has the linear expansion coefficient whose value is somewhere between those of center electrode 3 and noble metallic chip 5; therefore, it becomes possible to reduce the thermal stress occurring at the welding portion S when the spark plug for an internal combustion engine is repetitively used.

The function and effect of the embodiment of the present invention will be explained, hereinafter.

According to the above-described embodiment, the protruding portion 3c can be formed by sinking the noble metallic chip 5 into center electrode 3 by applying resistance welding. And, the noble metallic chip 5 can be easily fixed by the protruding portion 3c thus formed. By doing so, it becomes possible to reduce one step in the assembling process of fixing noble metallic chip 5 to center electrode 3.

Furthermore, by applying the laser welding through protruding portion 3c, it b comes possible to form the fusion

layer B which is capable of effectively r ducing the thermal stress occurring in the welding portion S between the noble metallic chip 5 and center electrode 3. In other words, the protruding portion 3c of the present embodiment has a function of forming the fusion layer B as well as a function of fixing the noble metallic chip 5.

Furthermore, according to the conventional arts, it was required that the noble metallic chip 5 had the thickness more than 1 mm in view of necessity of deeply inserting or engaging the noble metallic chip 5 in the bore (refer to Fig. 4A) formed on the center electrode 3. In this respect, the present embodiment allows to use the thin noble metallic chip 5 having the thickness of approximately 0.4 mm, leading to a great reduction of the amount of material of noble metallic chip 5.

Furthermore, the protruding portion 3c of the present embodiment is exposed to the outside. Hence, by irradiating the laser beam L, both of the protruding portion 3c and the center electrode 3, if they are vaporized, can be evaporated into the outside atmosphere. Accordingly, there is no possibility of causing a cavity in the fusion layer B or in the vicinity thereof even after the welding operation is finished, although the previously-described conventional arts are subjected to such a problem. Moreover, the present embodiment solves the problem of the micro holes residing in the noble metallic chip 5 and the electrode 3 before executing the welding operation, because these micro holes can freely depart from the noble metallic chip

5 or electrode 3 and go into the outside atmosphere once they grew into a large bubble upon melting of noble metallic chip 5 and electrode 3.

Furthermore, irradiating laser beam L to noble metallic chip 5 through protruding portion 3c is advantageous in that the component of center electrode 3 involved in the fusion layer B is not reduced. Still further, although laser beam L may induce a more or less amount of vaporization, swell of protruding portion 3c is effective to prevent the undesirable size reduction in the welding portion S.

With the fusion layer B thus formed, it becomes possible to reduce the thermal stress caused in the welding portion S and properly maintain the connecting strength between center electrode 3 and noble metallic chip 5.

Yet further, according to the welding method of the abov - described embodiment, noble metallic chip 5 and center electrode 3, which are largely different from each other in their linear expansion coefficient α, can be assembled firmly with an excellent connecting strength.

Assuming that H and W represent the height and the width of protruding portion 3c as shown in Fig. 3B, determining the size of protruding portion 3c as satisfying $H \geq 0.1mm$ and $W \geq 0.1mm$ will make it possible to smoothly mix protruding portion 3c and noble metallic chip 5 in the laser welding operation. With such size settings, it becomes possible to further eliminate the possibility of losing the component of center electrode 3

involved in fusion layer B thus formed. Accordingly, the fusion layer B effectively reduces the thermal stress occurring in the welding portion S.

Although the laser welding operation is performed along the entire periphery of noble metallic chip 5 according to the above-described embodiment, it is needless to say that the present invention is not limited to this arrangement. For example, as shown in Fig. 3E, it will be possible to apply the laser welding operation at only two points on the outer periphery of noble metallic chip 5. Alternatively, the laser welding can be applied at three points or more.

Furthermore, according to the above-described embodiment, center electrode 3 is made of heat-resistive nickel-group alloy (INCONEL 600 commercially available from Inconel Co., Ltd.) and noble metallic chip 5 is made of Ir. However, the present invention is not limited to these materials. Center electrode 3 can be made of other heat-resistive alloy material. And, noble metallic chip 5 can be made of other noble metallic material selected from the group consisting of Pt (lin ar expansion coefficient $\alpha = 9 \times 10^{-6}$, melting point $T_m = 1{,}770$ °C), 20Ir-80Pt (linear expansion coefficient $\alpha = 8.4 \times 10^{-6}$, melting point $T_m = 1{,}850$ °C), 80Pt-20Ni (linear expansion coefficient $\alpha = 9.4 \times 10^{-6}$, melting point $T_m = 1{,}550$ °C), Ir-Pt, Ir-Pt-Ni, Ir-Rh, Ir-W, Ir-Al, Ir-S, Ir-Y, Ir-Y_2O_3.

Moreover, according to the above-described embodiment, the laser welding is used as welding capable of condensing energy.

The present invention is, however, not limited to this laser welding. For example, electron beam welding will be us d as alternative welding capable of condensing energy.

As this invention may be embodied in several forms without departing from the spirit of essential characteristics thereof, the present embodiments described are therefore intended to be only illustrative and not restrictive, since the scope of the invention is defined by the appended claims rather than by the description preceding them, and all changes that fall within the metes and bounds of the claims, or equivalents of such metes and bounds, are therefore intended to be embraced by the claims.

CLAIMS

1. A spark plug for an internal combustion engine comprising a center electrode, an earth electrode and a noble metallic chip welded to at least one of said center electrode and said earth electrode, characterised in that

a protruding portion is formed around the outer periphery of the or each noble metallic chip by forcibly pressing said noble metallic chip against part of said at least one electrode, so that said protruding portion holds said noble metallic chip onto said electrode, and

the or each said noble metallic chip is welded to the respective electrode by irradiating said noble metallic chip with energy-condensing light through said protruding portion.

2. A spark plug for an internal combustion engine comprising a center electrode, an earth electrode and a noble metallic chip welded to at least one of said center electrode and said earth electrode, characterised by

a protruding portion formed around the outer periphery of the or each said noble metallic chip by partly extruding the tip of the electrode, so that said noble metallic chip is held by said electrode by means of said protruding portion, and

a fusion layer comprising part of the or each noble metallic chip and part of the electrode which parts are fused and mixed each other, said fusion layer extending from said noble metallic chip to the outside of said

protruding portion so that said fusion layer is exposed to the outside atmosphere.

3. The spark plug for an internal combustion engine in accordance with claim 1 or 2, wherein said protruding portion is formed by bringing the or each noble metallic chip into contact with the electrode, and melting the electrode at the surface brought into contact with said noble metallic chip, then sinking said noble metallic chip into the melted portion of said electrode so that the melted portion of said electrode is raised around the outer periphery of said noble metallic chip.

4. The spark plug for an internal combustion engine in accordance with any one of claims 1 to 3, wherein said protruding portion has a height not smaller than 0.1mm and a width not less than 0.1mm.

5. The spark plug for an internal combustion engine in accordance with any one of claims 1 to 4, wherein the or each noble metallic chip is made of noble metallic material selected from the group consisting of Ir, Ir-Pt, Ir-Pt-Ni, Ir-Rh, Ir-W, Ir-Al, Ir-Si, Ir-Y, Ir-Y_2O_3, and the or each chip is welded to an electrode made of Ni-group heat resisting alloy.

6. The spark plug for an internal combustion engine in accordance with any one of claims 1 to 5, wherein the or each noble metallic chip is made of

an Ir alloy having a linear expansion coefficient α not smaller than 8×10^{-6}, and is welded to an electrode made of Ni-group heat resisting alloy having a linear expansion coefficient α not smaller than 13×10^{-6}.

7. A manufacturing method for a spark plug used in an internal combustion engine comprising the steps of:

melting part of an electrode at a predetermined region where a noble metallic chip is to be fixed;

sinking said noble metallic chip into the melted portion of said electrode by applying a pressing force;

forming a protruding portion around the outer periphery of said noble metallic chip by extruding the melted portion of said electrode when said noble metallic chip is sunk into said melted portion of said electrode; and

welding said noble metallic chip with said electrode by irradiating it with energy-condensing light through said protruding portion.

8. A spark plug substantially as described herein with reference to Figs. 1, 2 and 3A to 3E of the accompanying drawings.

9. A method of manufacturing a spark plug as described herein with reference to Figs. 1, 2 and 3A to 3E of the accompanying drawings.

The Patent Office

Application No:	GB 9621237.8	Examiner:	John Twin
Claims searched:	1 to 9	Date of search:	10 December 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F1B (BCAN)

Int Cl (Ed.6): H01T 13/20, 13/32

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	None	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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